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IMPROVEMENT OF INERTIAL ELECTROSTATIC CONFINEMENT DEVICE BY MAGNETRON-DISCHARGE-BASED BUILT-IN ION SOURCES

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An inertial-electrostatic confinement fusion (IECF) device is a compact discharge-type fusion neutron/proton source, consisting of a spherical vacuum chamber as an anode, and a central hollow cathode grid, where a glow discharge takes place. In the IECF device, positive ions generated by glow discharge are accelerated toward the center, and mostly after passing through the hollow cathode, and again accelerated toward the center. These re-circulating ions result in a high ion density at the center, and accordingly a high fusion reaction rate. Production of sufficient amount of ions near by the anode and reduction of unnecessary charge-exchange with background gases are both essential for a enhancement of ions' energy and lifetime leading to a higher fusion reaction rate.

For this purpose, we have proposed a magnetron discharge-type built-in ion source. Unlike other external ion sources, this ion source does not require additional positive extraction electric fields, which tend to make the ions to hit to the opposite chamber wall. Moreover, the magnetron type built-in ion source has an extremely simple configuration to preserve the advantageous IECF features of compactness and robustness, essential for practical application.

The built-in magnetron discharge system consists of an anode (grounded nozzle of 35 mm ϕ inner diameter), a coaxial cathode (20 mm ϕ diameter) at a negative voltage, and a cylindrical water-cooled permanent magnet (Nd-Fe) inside the cathode tube. This magnetron-type ion source shows a good performance of discharge current as high as 60 mA at a cathode voltage of 3.0 kV under H_2 gas pressure of 3.0 Pa. The IECF device assisted by this magnetron ion source can maintain discharge under low gas pressure condition of less than 0.5 Pa.

It is found that in this magnetron-ion-source-assisted IECF device, there are three operation modes of glow discharge, glow-magnetron hybrid discharge, and ion injection mode. The glow discharge mode takes place under conditions of normal (~2 Pa) gas pressures. The hybrid discharge mode shows line-shape discharge under conditions of low gas pressures and intermediate cathode voltages, and the ion beam-injection mode shows no glow discharge under low gas pressures and high cathode voltages. Dependencies of cathode voltage, cathode current, and gas pressure are completely different in each operation mode and that makes it difficult to compare neutron yield directly. We then evaluate improvement of the IECF device in terms of neutron yield normalized by cathode current and gas pressure, which is approximately proportional to $<\sigma v>$ (where σ is fusion cross section and v is velocity of D ion). In hybrid mode, the normalized neutron yield is found higher than glow mode, and in the case of beam fusion mode, the normalized yield is found more than 2 times higher. The results strongly imply enhancement of the ion beam energy, which is very encouraging for a further drastic improvement of IECF performance.